Sex linkage

1. **Sex chromosomes**
2. **Sex determination in animals**
3. **Environmental sex determination**
4. **Sex determination in humans**
5. **Genic balance theory**
6. **Drosophila gynandromorph**
7. **Sex determination in plants**
8. **Introduction to Sex linkage and Sex linked traits and sex linked inheritance**
9. **Sex limited traits and sex influenced traits**

Rashmi M G

Sex chromosomes

Chromosomes

- Autosomes
- Sex chromosomes/ Allosomes

During meiosis

- In Females, 2X chromosomes Pair Segregate like autosomes Each female gamete receives one X chromosome **Homogametic sex**
- In Males, X and Y chromosome both Pairs Segregates Half of male gamete receive X and other Half receive Y **Heterogametic sex**

Human body cells
Total = 46 chromosomes

- 22 homologous pair of Autosomes
- 2 Sex chromosomes/ Allosomes

Organism's Sex is Determined by special sex chromosome

Organism is said to be,

- Male 22A+XY **Heteromorphic**
- Female 22A+XX **Homomorphic**

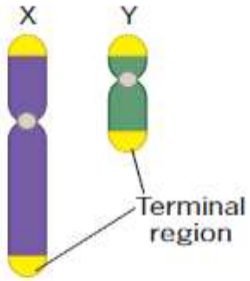
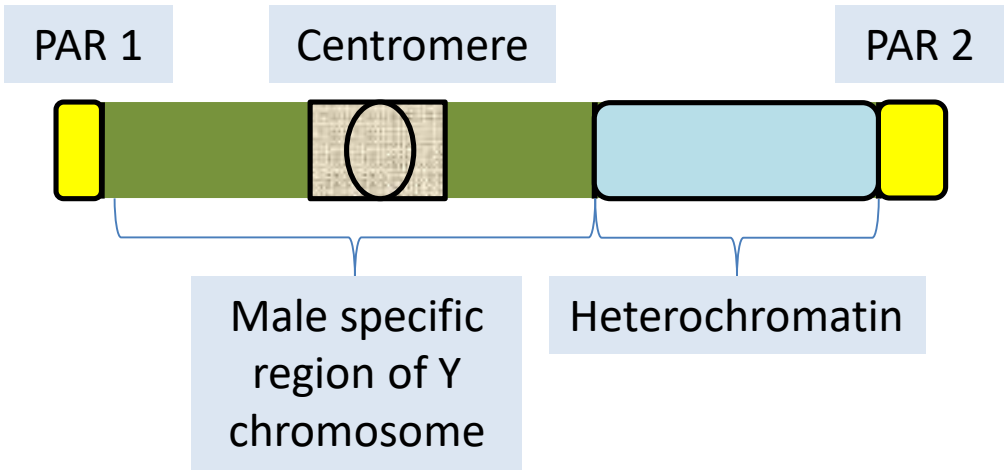


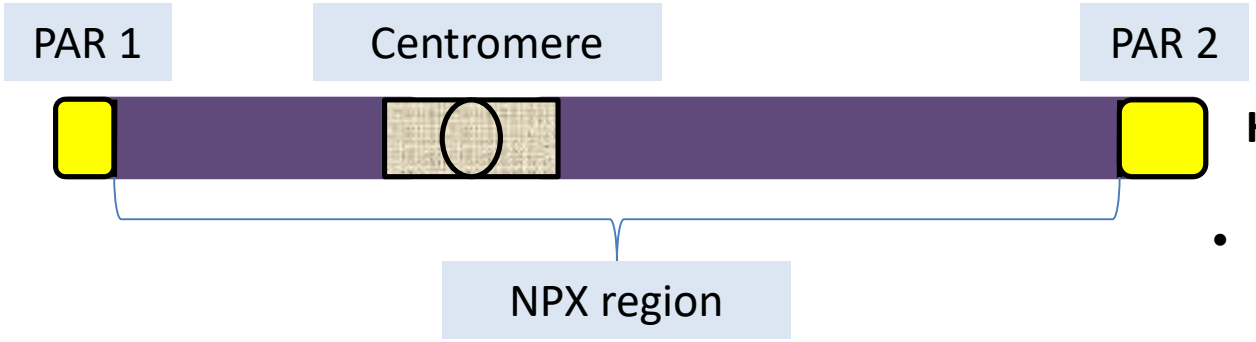
FIGURE 5.2 Human X and Y chromosomes. The terminal regions are common to both sex chromosomes.



Human Y chromosome

3 Regions:

- Male Specific region of Y chromosome
- Pseudoautosomal regions (PAR1 and 2)
- Heterochromatin region



Human X chromosome

2 regions:

- Pseudoautosomal regions (PAR1 and 2)
- Heterochromatin region

Sex determination in animals

Hermaphrodites –individuals having both male and female sex organs

Simultaneous hermaphrodites
Contain both male and female sexual organs simultaneously
Ex. Gastropods, Earthworms

Sequential hermaphrodites
Born males and change into females/ begin life as female and then change to males
Ex. Fishes

Sex determination mechanisms are of 2 types:

Genotypic
Based on genotype
Ex. Mammals, Birds, Amphibians, Insects, Reptiles, Fishes

Environmental
Based on the influence of Environmental aspects like temperature, pH, Social interactions, Seasonality
Ex. Crocodiles, Turtles and lizards

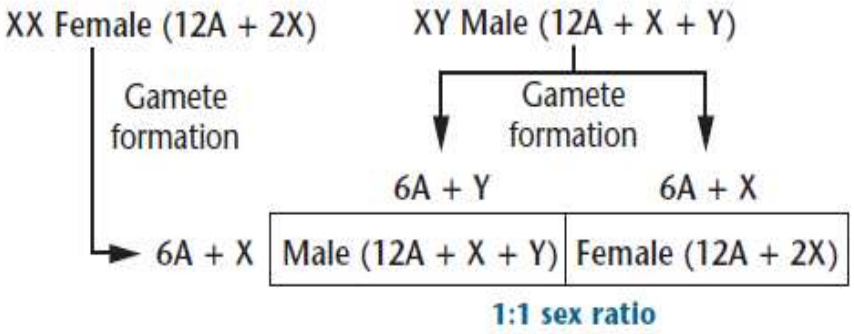
4 Types of chromosomal Sex Determination mechanisms

XY System

Female- Homogametic- XX

Male-Heterogametic –X

Ex. Mammals, Flies, Fishes



ZW System

Female- Heterogametic- ZW

Male- Homogametic- ZZ

Ex. Birds, Snakes, Butterflies

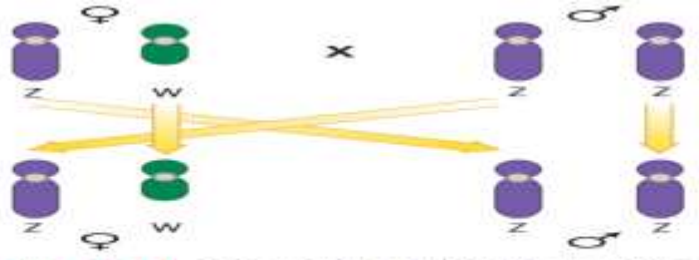
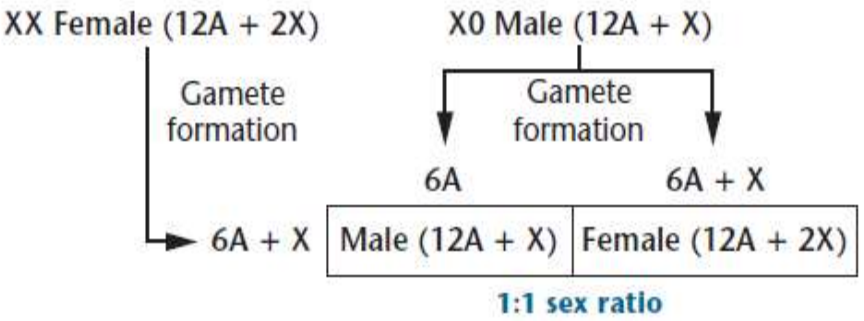


FIGURE 5.13 Sex determination in birds. The female is heterogametic (ZW), and the male is homogametic (ZZ). The sex of the offspring is determined by which of the sex chromosomes, Z or W, is transmitted by the female.

XO System

Female- 2X –XX

Male-1X-XO



Haplodiploid System

Female- Fertilized egg(diploid)

Male-Unfertilized egg (Haploid)

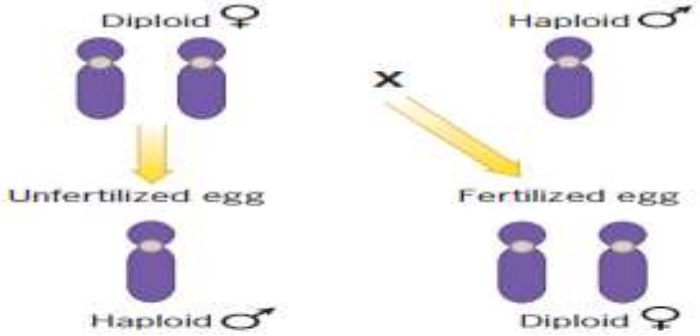
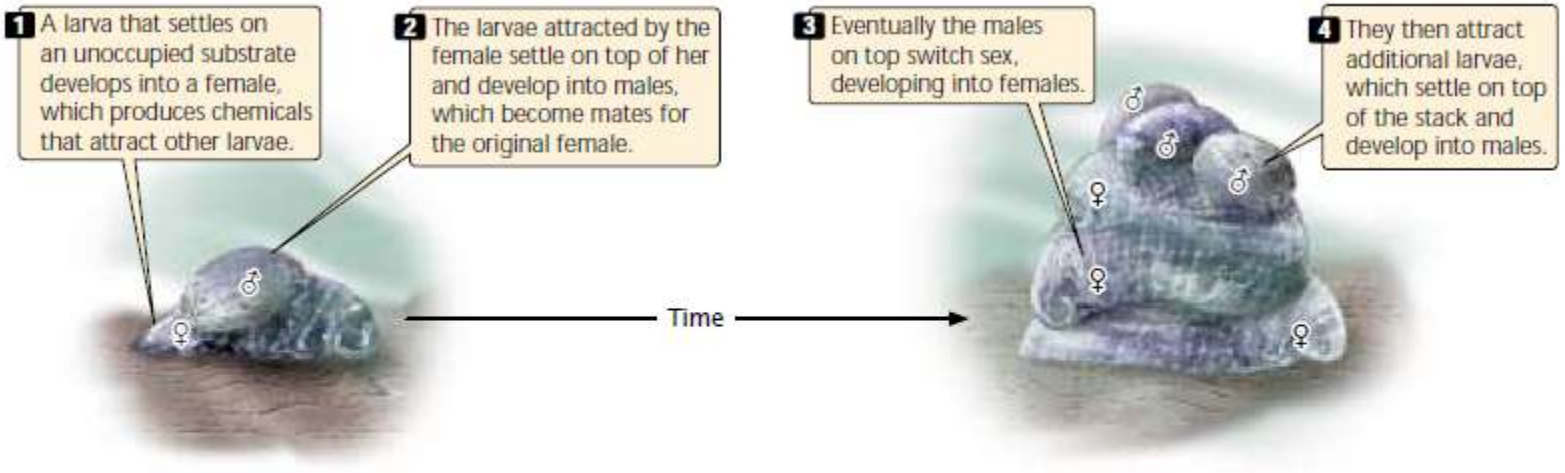


FIGURE 5.14 Sex determination in honeybees. Females, which are derived from fertilized eggs, are diploid, and males, which are derived from unfertilized eggs, are haploid.

Environmental sex determination

Sex determination- based on temperature at which egg is incubated during temperature sensitive period

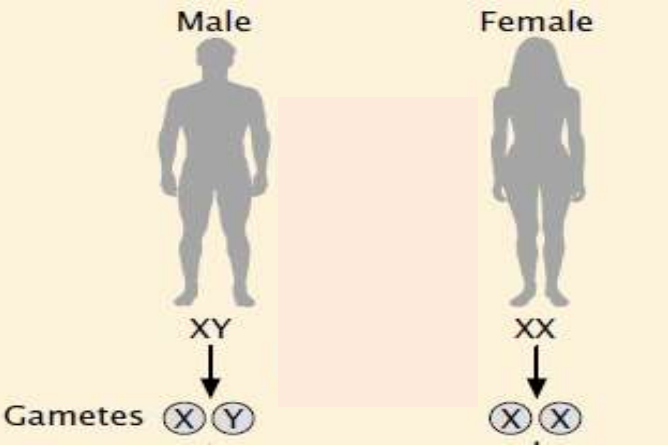

1 A larva that settles on an unoccupied substrate develops into a female, which produces chemicals that attract other larvae.
2 The larvae attracted by the female settle on top of her and develop into males, which become mates for the original female.
3 Eventually the males on top switch sex, developing into females.
4 They then attract additional larvae, which settle on top of the stack and develop into males.
Time

4.8 In *Crepidula fornicata*, the common slipper limpet, sex is determined by an environmental factor, the limpet's position in a stack of limpets.

Source: Benjamin A Pierce, Genetics, A conceptual approach, Page no.81

Sex determination in humans

XX-XY System
XX- Female
XY- Male
Primary sex determination- presence of Y chromosome



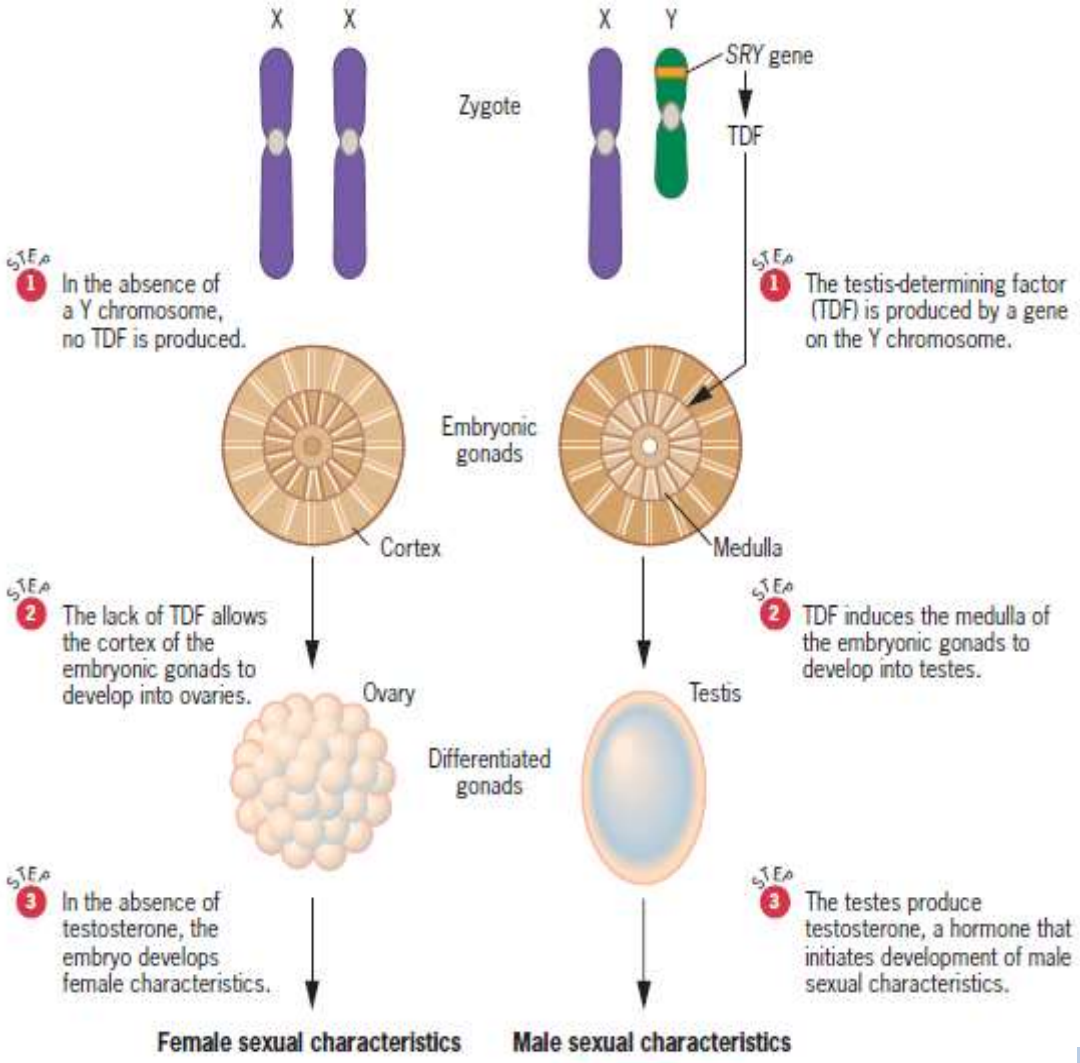
SRY gene (Sex Determining Region Y) located on Short arm of Y chromosome

→ Activity of **TDF** (Testes Determining Factor)

Expressed only in subset of somatic cells of developing gonad

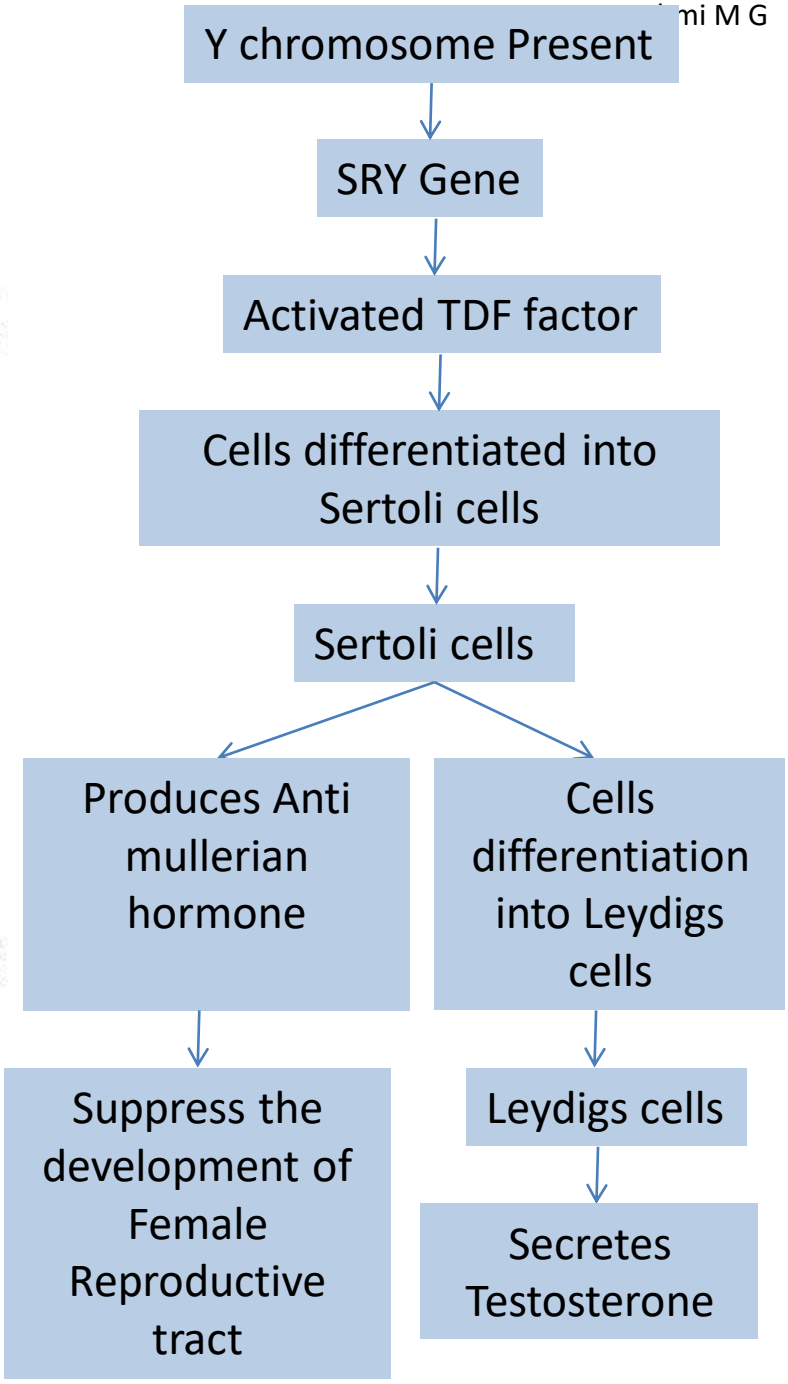
1. Responsible for development of testes
2. Differentiates Cells into Sertoli cells
3. Produces Anti- Mullerian Hormone
4. Helps to induce other somatic cells in developing gonads to become Leydigs Cells

Note:
Anti Mullerian hormone- Suppress development of Female Reproductive tract
Leydigs Cells- Secretes Male sex hormone


X X
Zygote
X Y
SRY gene
TDF
STEP 1 In the absence of a Y chromosome, no TDF is produced.
STEP 1 The testis-determining factor (TDF) is produced by a gene on the Y chromosome.
Embryonic gonads
Cortex
Medulla
STEP 2 The lack of TDF allows the cortex of the embryonic gonads to develop into ovaries.
STEP 2 TDF induces the medulla of the embryonic gonads to develop into testes.
Ovary
Testis
Differentiated gonads
STEP 3 In the absence of testosterone, the embryo develops female characteristics.
STEP 3 The testes produce testosterone, a hormone that initiates development of male sexual characteristics.
Female sexual characteristics
Male sexual characteristics

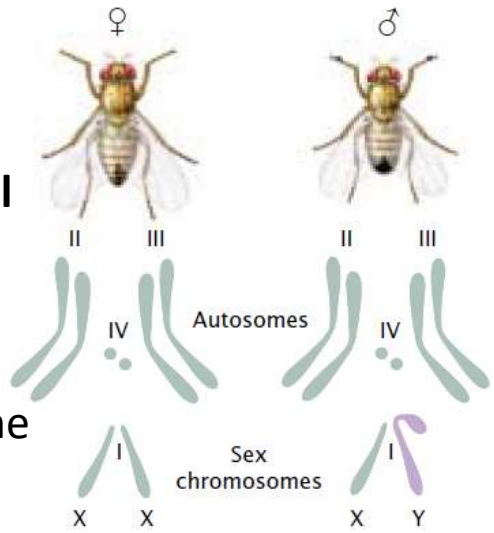
■ **FIGURE 5.10** The process of sex determination in humans. Male sexual development depends on the production of the testis-determining factor (TDF) by a gene on the chromosome. In the absence of this factor, the embryo develops as a female.

Source: Snustad, Simmons (2012), Principles of genetics, John Wiley& Sons, Inc, Sixth edition, Page no.101



Genic Balance Theory
Sex Determination in Drosophila

XX-XY system
XX- Female
XY- Male
Sex Determination – Based on Balance (Ratio) of **Autosomal alleles** that **favors Maleness** and **Alleles on X chromosome favors Femaleness**
Normal diploid male- 2 sets of autosomes+ XY
Normal diploid Female- 2 sets of autosomes+ X chromosome



4.9 **The chromosomes of *Drosophila melanogaster* ($2n = 8$) consist of three pairs of autosomes (labelled I, II, and III) and one pair of sex chromosomes (labelled X and Y).**

Source: Benjamin A Pierce, Genetics, A conceptual approach, Page no.83

Table 4.1 Chromosome complements and sexual phenotypes in *Drosophila*

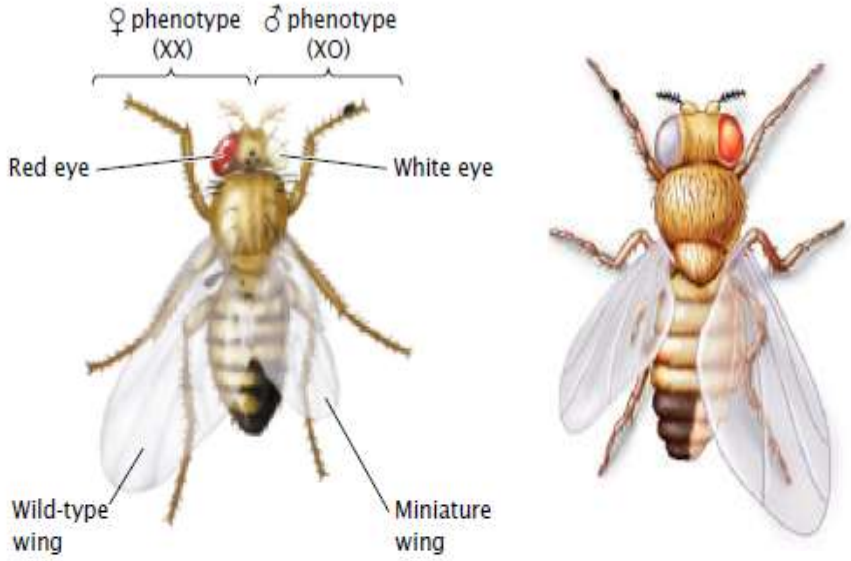
Sex-Chromosome Complement	Haploid Sets of Autosomes	X:A Ratio	Sexual Phenotype
XX	AA	1.0	Female
XY	AA	0.5	Male
XO	AA	0.5	Male
XXY	AA	1.0	Female
XXX	AA	1.5	Metafemale
XXXY	AA	1.5	Metafemale
XX	AAA	0.67	Intersex
XO	AAA	0.33	Metamale
XXXX	AAA	1.3	Metafemale

Drosophila Gynandromorphs

Gynandromorphs – both male and female characteristics in single individual
Bilateral asymmetry (half male: half female)/ mosaic
Caused by:

- Non disjunction
- Chromosomal lagging during mitosis zygote / in nuclei in early embryo
- If X chromosome is lost in one of dividing somatic cells, results in.
  - XX Cell line – Female
  - XO Cell line – Male

Gynandromorphs differ from intersexes
Gynandromorphs- consists of 2 genetically different tissues
Intersex- genetically similar throughout their bodies ,usually sterile



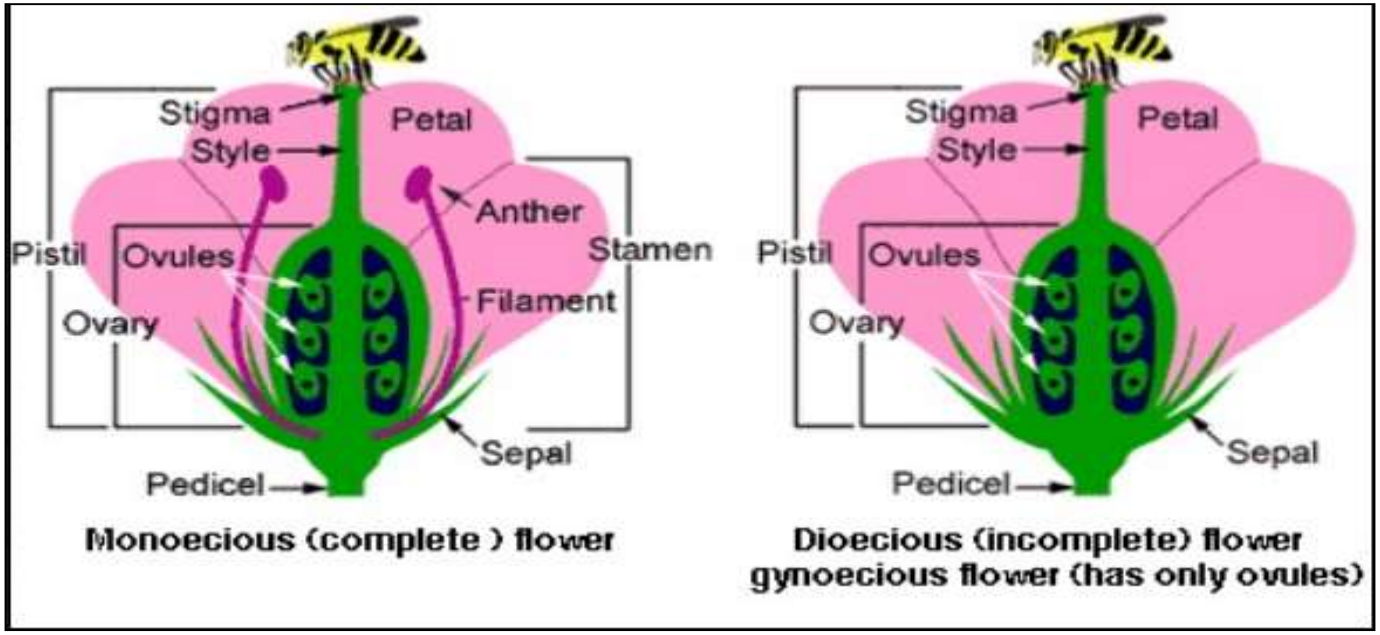
9.26 **Mosaicism for the sex chromosomes produces a gynandromorph.** This XX/XO gynandromorph fruit fly carries one wild-type X chromosome and one X chromosome with recessive alleles for white eyes and miniature wings. The left side of the fly has a normal female phenotype, because the cells are XX and the recessive alleles on one X chromosome are masked by the presence of wild-type alleles on the other. The right side of the fly has a male phenotype with white eyes and miniature wing, because the cells are missing the wild-type X chromosome (are XO), allowing the white and miniature alleles to be expressed.

Source: Benjamin A Pierce, Genetics, A conceptual approach, Page no.254

Sex determination in plants

Sexually **Monomorphic**,
Individual plants have both sexes
Whether present within single flower (**Hermaphrodite**) / in separate male and female flowers (**Monoecious**)

Sexually **Polymorphic**,
Includes **Dioecious** species
Animal like sexual **dimorphism**
Female- **Unisexual** flower with only **carpels**
Male- **Unisexual** flower with only **stamens**



http://animagro.blogspot.com/2013/06/monoecious-and-dioecious-plants.html

Sex linked traits and sex linked inheritance

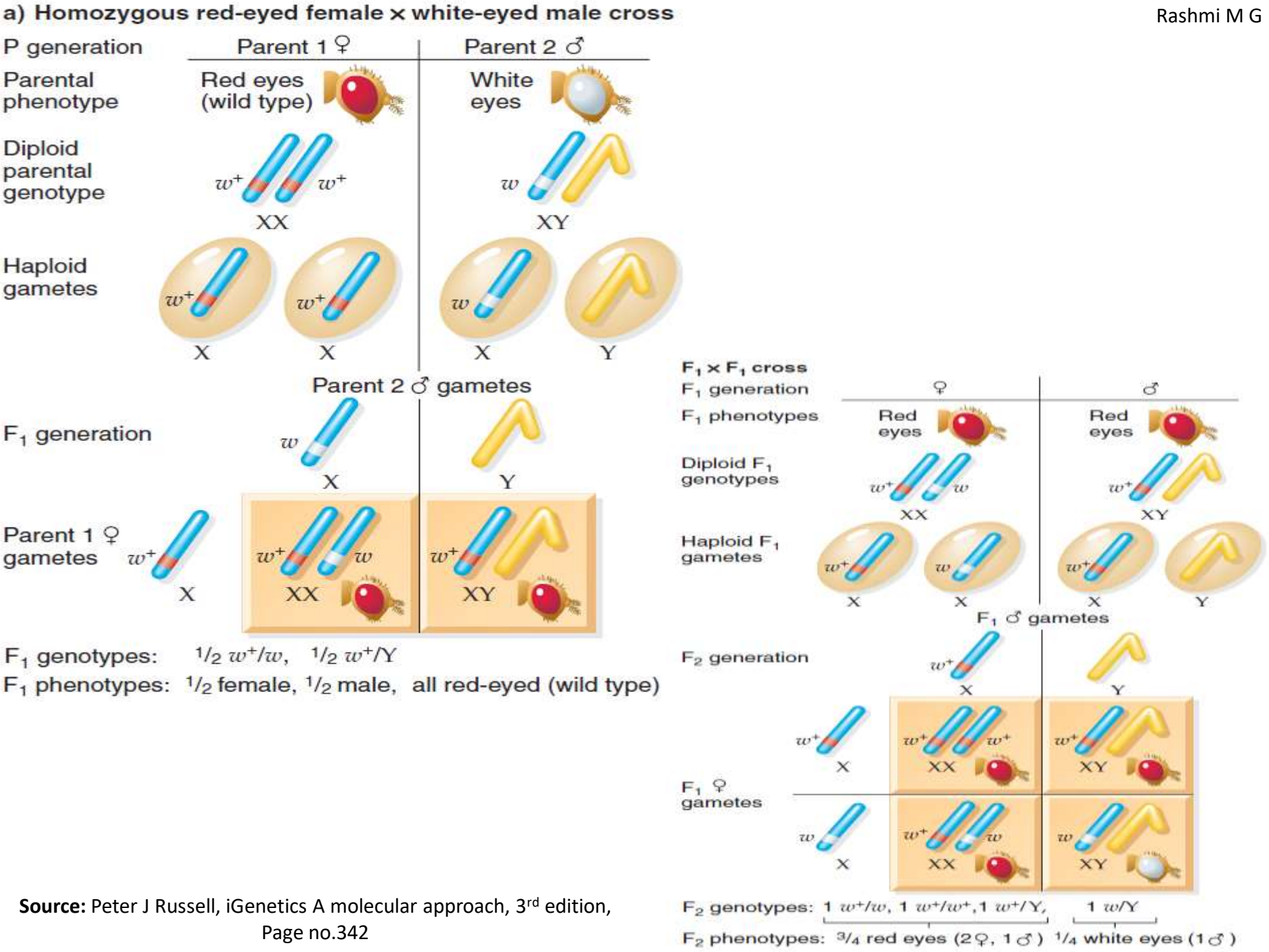
Genes on sex chromosomes- **Sex linked genes**
X- linked - Loci found only on X Chromosomes
Y- linked- Loci found only on Y chromosomes (Control Holandric traits)
X and Y chromosomes- Has **Homologous**, **Non Homologous regions** and **Differential regions**
Differential regions- Contain genes that have no counterparts on other sex chromosome
Genes on the differential region- **Hemizygous** (Half zygous)
Genes in differential region of X- Show inheritance pattern= **X Linkage**
Genes in differential region of Y- Show inheritance pattern = **Y linkage**
Genes in homologous region- Show inheritance pattern= **X and Y linkage**

Ex. Cross between White eyed male fly with red eyed female fly
Sex chromosome alleles are inherited in association with sex of offsprings

Alleles on Male's X chromosome → **Daughter** → **Son**

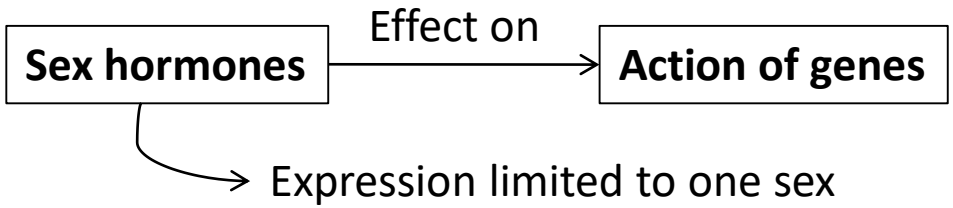
Not to his sons
Because the presence of his X chromosome normally determines that his offspring is a daughter

Criss cross pattern of inheritance



Source: Peter J Russell, iGenetics A molecular approach, 3rd edition, Page no.342

Sex Limited traits



Genes may be present on both sex
But expression is only in one particular sex

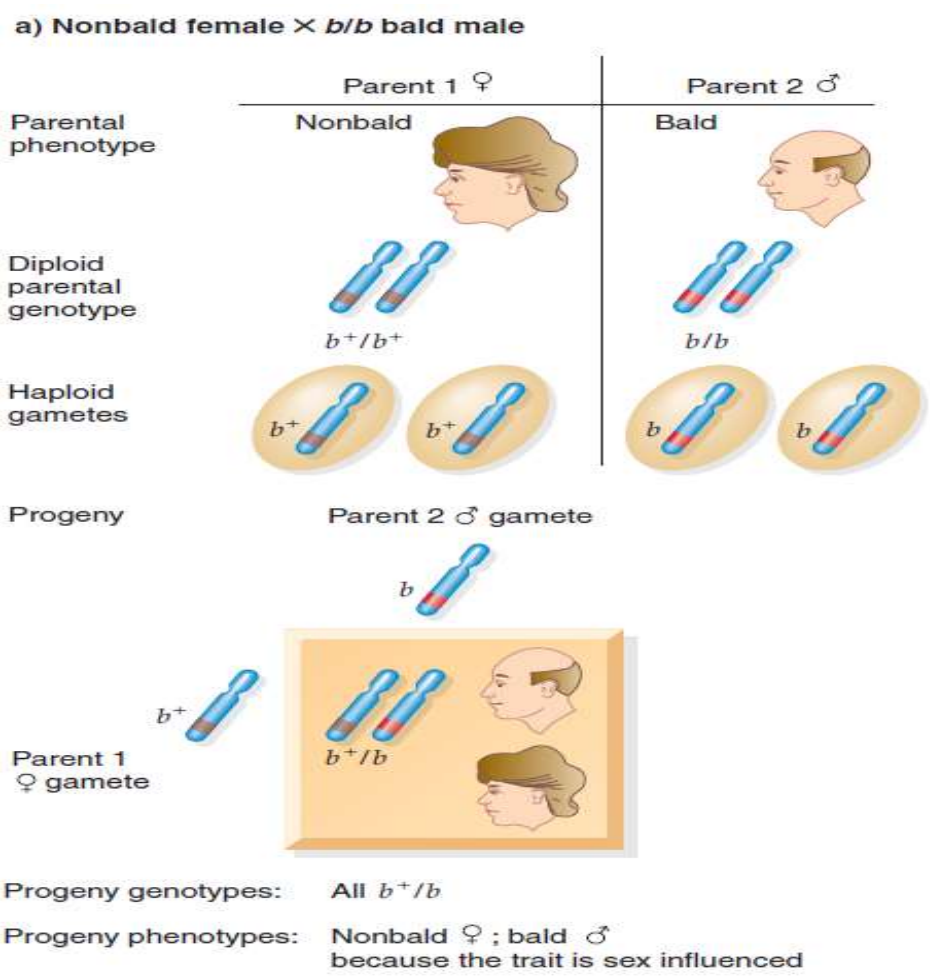
Sex limited traits usually determined by autosomal genes and primarily concerned with secondary characters

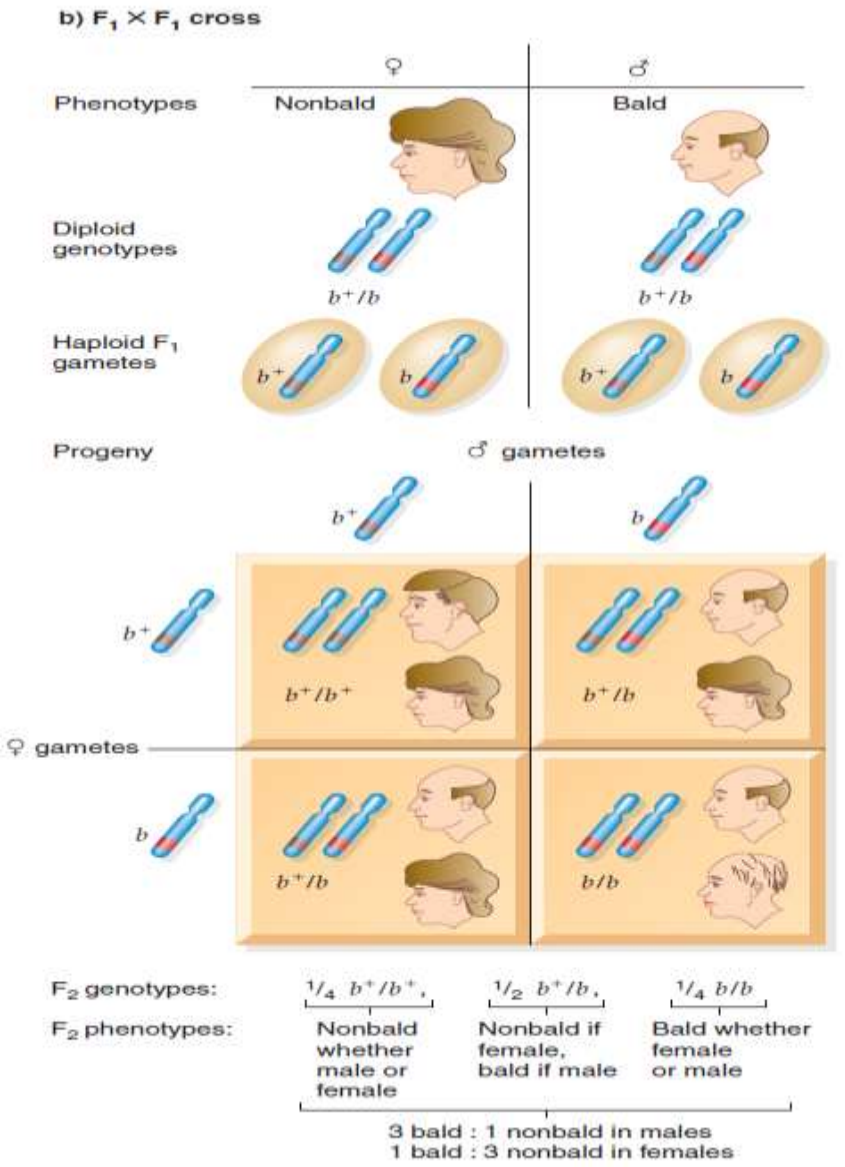
Ex. Beard in Male
Breast development in Female

Sex influenced traits

Sex controlled characteristics only the dominance relationship of two alleles is affected
Genes cause pattern baldness inherited as autosomal trait
Alleles is dominant in one gender and recessive in opposite gender
Ex. Pattern baldness in humans

Genotype	Male	Female
BB	Bald	Bald
Bb	Bald	Non bald
bb	Non bald	Non bald





Source: Peter J Russell, iGenetics A molecular approach, 3rd edition, Page no.374